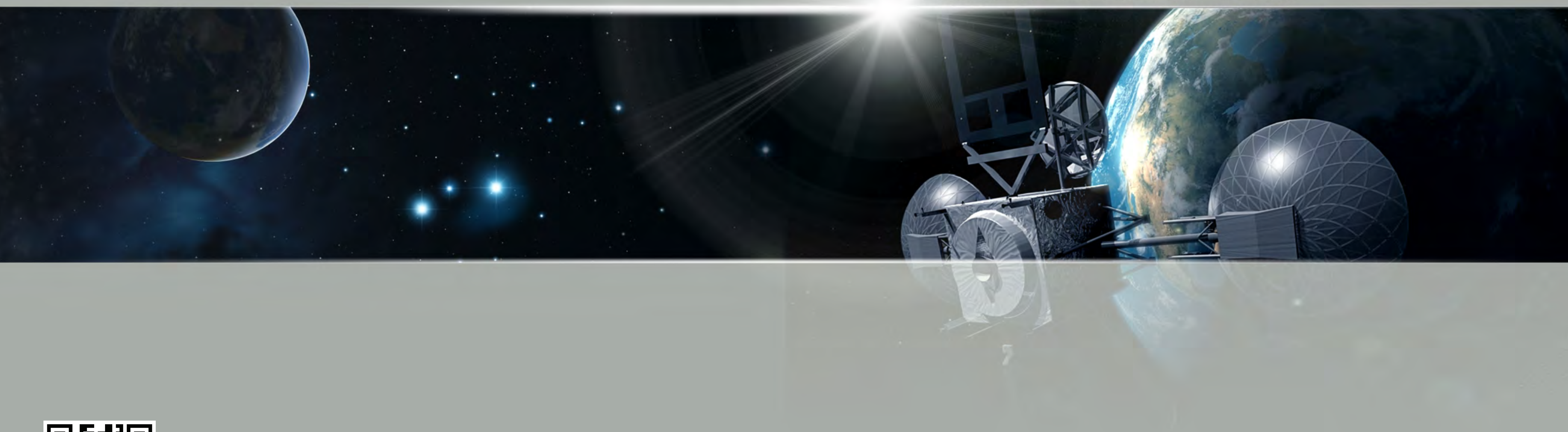
National Aeronautics and Space Administration

Tracking and Data Relay Satellite

Continuing the Critical Lifeline



National Aeronautics and Space Administration

Tracking and Data Relay Satellite Project
Goddard Space Flight Center, Code 454
Greenbelt, MD 20771
http://tdrs.gsfc.nasa.gov

www.nasa.gov

NP-2012-09-336-GSFC

A HISTORY OF CONNECTING TO THE FUTURE

In the past, spacecraft beamed data back from space down to domestic and international ground stations. The time these spacecraft could broadcast from low-Earth orbit was limited to a few minutes when they passed above a ground station. The terrestrial communication networks that moved the data from the stations to a control center suffered from a variety of challenges, from regional weather to political instability, often with unintended delays in receiving essential information. The Tracking and Data Relay Satellites (TDRS) presented an alternative. The nine TDRS spacecraft deployed since 1983 have transformed the ways NASA not only handles communications, but also its overall mission designs. With confidence that high bandwidth, highly-reliable communication will always be available, NASA has had the technological freedom to aim high.

TDRS users include some of the most storied NASA missions of all time. The Hubble Space Telescope, Landsat, and NASA's Earth Observing Satellites such as Terra, Aqua, Aura, and many others, have all used the Space Network to communicate with the ground. While not originally anticipated, the network has grown to become a vital relay for data from the South Pole research station operated by the National Science Foundation. Overall, the system has not only been the workhorse for communication, but also a platform on which actual scientific research has been conducted, including exploration into radio frequency propagation and very long baseline interferometry for studying various astrophysical phenomena.

Missions Above:

1.Hubble Space Telescope
http://www.nasa.gov/hubble

2. Aura
http://www.nasa.gov/aura

3. Terra
http://www.nasa.gov/terra

4. Aqua
http://www.nasa.gov/aqua

5. International Space Station
http://www.nasa.gov/station.l

6. Landsat-7
http://landsat.gsfc.nasa.gov/

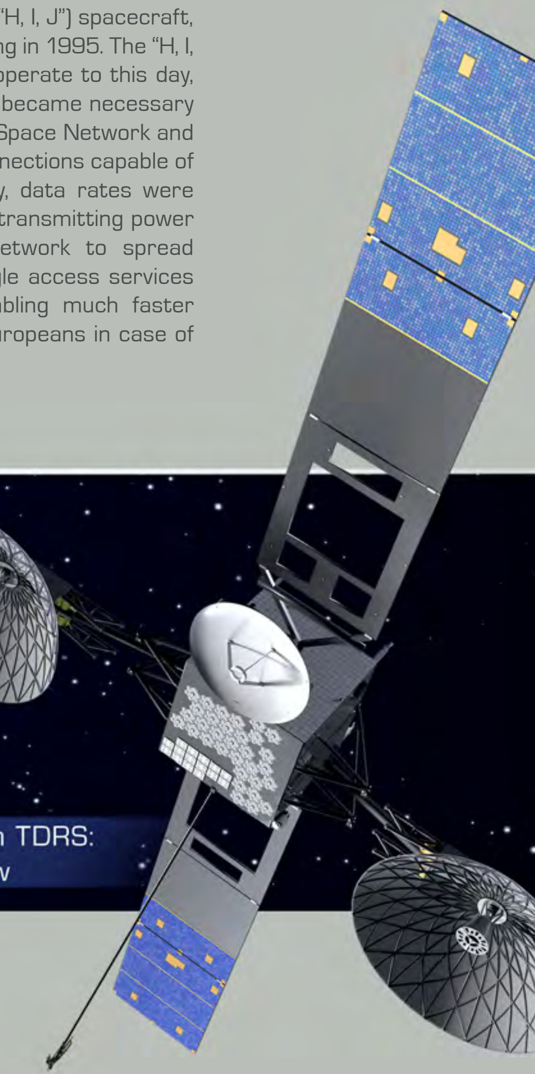
A NEW CENTURY, A NEW GENERATION

With a wide variety of science missions and active spacecraft relying on the Space Network, it's not just the quantity of data that matters; it's the speed of delivery. To satisfy both and to ensure vital operational continuity, NASA is preparing to deploy new communications spacecraft for a new century. In the space community, they are called TDRS "K", "L", and "M".

Recognizing a need for higher volumes of data at faster delivery rates, NASA began to think differently about how spacecraft data was transmitted. Designed to handle an increase in data volume and to provide total coverage for low-Earth-orbiting spacecraft, the program launched TDRS-1 in April of 1983.

NASA continued to add first generation TDRS spacecraft until 1995. A total of seven were built with six becoming operational; TDRS-2 was lost aboard Challenger.

The second generation of the TDRS program, the eighth, ninth, and tenth ("H, I, J") spacecraft, entered the planning phase as soon as the first generation finished launching in 1995. The "H, I, J" spacecraft were launched between 2000 and 2002 and continue to operate to this day, along with members of the aging first generation. The second generation became necessary because of expanded communication requirements from those using the Space Network and general advancements in technology that demanded higher bandwidth connections capable of delivering greater volumes of information at higher speeds. Accordingly, data rates were increased to more than thirty times that of the first generation fleet and transmitting power was also increased significantly. These two changes enabled the network to spread communications over new multiple-user services, where before only single access services were available. In addition to this, Ka-band capability was added, enabling much faster transmissions as well as international compatibility with Japanese and Europeans in case of emergencies.



The third generation of spacecraft ("K, L, & M") has already been planned for the coming years and will continue to deliver long-lasting spacecraft for Space Network operations. As the aging first generation spacecraft are retired, the third generation will take their place and keep the communications fleet fully operational.

TDRS – ARCHITECTURE AND OPERATIONS

NASA's Space Network is the combination of high-performance geosynchronous TDRS and an associated, robust ground segment.

Initially designed to deliver 24/7 routing of data for critical NASA missions in low-Earth orbit, the Space Network has shown surprising flexibility and expandability for demanding uses far beyond initial goals.

The Space Network keeps users in contact with their spacecraft no matter where that spacecraft happens to be.

A constellation of at least three TDRS spacecraft, operating from a geosynchronous orbit, are always overhead and capable of communicating data, essentially providing an unbroken web for uplinked and downlinked communication.

There are complexities for a system as powerful and sophisticated as TDRS, but there are a few basic components worth breaking out for explanation.

The TDRS K, L, and M spacecraft have two main components: a bus and a payload, and requires modifications to the ground segment to allow the mission to become operational within the group of relay satellites known as the constellation.

Most automated spacecraft are built around a bus. The bus is a chassis in which essential cargo and equipment ride. The bus selected for TDRS K, L, and M is a Boeing BSS-601. One of the most widely-used buses ever designed for communications satellites, the 601 series has been used on more than 70 communications satellites and serves as the primary spacecraft bus for the TDRS second and third generation spacecraft.

THE BUS

The evolved version of the 601 bus being used for K, L, and M supports high-performance gallium arsenide solar panels capable of powering a wide variety of services. After 15 years in orbit, both wings together generate around 3000 watts of power. Each solar array wing consists of three deployable panels with Ultra Triple Junction (UTJ) cells on the outer-most panel and a third on the center panel. These solar cells are specially designed for efficiency and resistance to radiation, both vital for the long-term durability and reliability of the TDRS spacecraft.

The bus is broken into two principal modules. One module contains the propulsion system, bus electronics, and batteries; the other module is composed of honeycombed shelves for protection of heat pipes, electronics, and mission-critical communications equipment. Solar arrays, antennas, and deployable bus and payload elements are mounted on both modules.

All together, these are big satellites. Fully deployed, they weigh in at nearly 4,000 lbs and have a wingspan greater than 65 feet. That's roughly six stories tall!

PAYLOAD

Communication satellite payloads are generally comprised of antennas, amplifiers, frequency conversion, and connecting communication equipment. This equipment is carefully designed, tested, and integrated with the bus to create a functional spacecraft.

Operating these payloads require communications for command and control. When these spacecraft are launched, they are designed to send nominal tracking and telemetry signals and receive general service commands simply for the purpose of keeping everything in working order; call it spacecraft housekeeping.

The primary payload of each TDRS is the microwave communications equipment with associated gimbaled antennas. The communications systems of the TDRS Spacecraft are designed to provide services to multiple missions simultaneously. Each TDRS has S-band and Ku-band equipment. Second and third generation spacecraft also include Ka-band functionality. With the addition of Ka-band capabilities, the TDRS spacecraft dramatically improved their overall service potential by substantially increasing bandwidth and data rates.

SINGLE ACCESS ANTENNA
provides S-, Ku-, and Ka-band

S- band Single Access

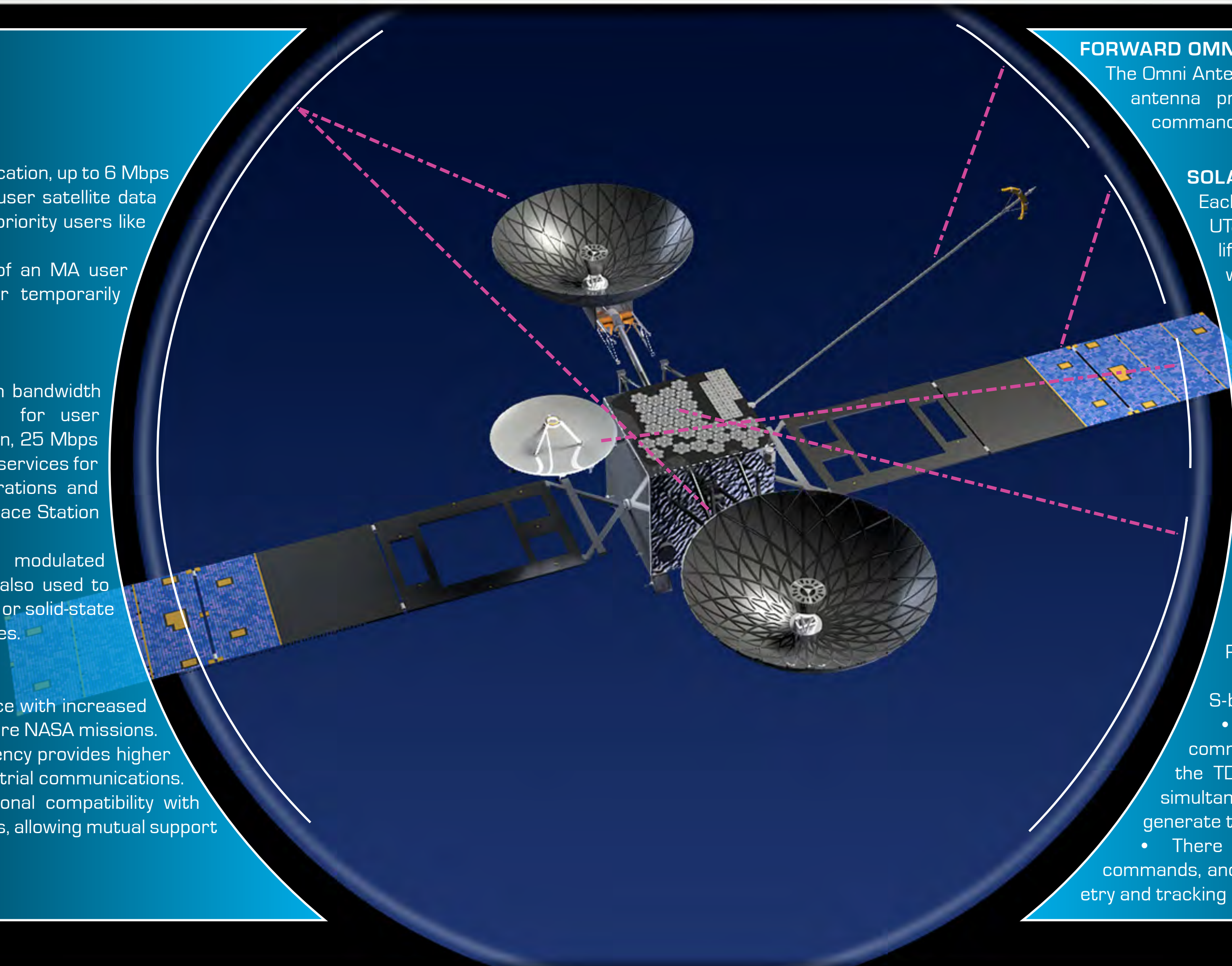
- General usage - two-way communication, up to 6 Mbps return, 7 Mbps forward data rates, during user satellite data dumps, or full-time high-rate service to high-priority users like the International Space Station.
- Can provide high gain support of an MA user satellite with degraded communications or temporarily provide an increased data rate.

Ku-band Single Access

- Ku-band frequencies provide high bandwidth and better communication performance for user satellites with data rates to 300 Mbps return, 25 Mbps forward. Ku-band is also capable of providing services for high-resolution digital television for teleoperations and science requirements of the International Space Station (ISS) and it's visiting resupply vehicles.
- Currently provides frequency modulated television for all ISS video communications; also used to rapidly dump large volumes of data from tape or solid-state data recorders aboard NASA science satellites.

Ka-band Single Access

- Ka-band is a high-frequency service with increased data rate capabilities up to 800 Mbps for future NASA missions. An advantage of Ka-band is the higher frequency provides higher bandwidths and less interference with terrestrial communications.
- Ka-band also provides international compatibility with Japanese and European space relay programs, allowing mutual support in case of emergencies.



FORWARD OMNI ANTENNA
The Omni Antenna is a log-spiral antenna flown on several satellites. The antenna provides broad coverage for tracking, telemetry, and command functions.

SOLAR ARRAY
Each solar array wing consists of three deployable panels with UTJ cells on outermost panel and half of center panel. After a lifespan of 15 years, both wings together generate 3220 watts during autumnal equinox and 2850 watts during summer solstice.

SPACE-TO-GROUND LINK ANTENNA
The SGL antenna serves as the primary communication link between TDRS and the ground terminal at the White Sands Complex in New Mexico. The SGL antenna provides a high gain beam to the ground terminal and allows simultaneous operation to transmit and receive data.

MULTIPLE ACCESS FORWARD ANTENNAS
Providing S-band

MULTIPLE ACCESS RETURN ANTENNAS
Providing S-band

S-band Multiple Access

- The Multiple Access Services operates in the S-band communications frequency and uses phase array anetnnas on the TDRS satellites to communicate with multiple spacecraft simultaneously, assisting several low-rate, long-duration users that generate time-sensitive data.
- There are 15 forward antenna elements used for uplinking commands, and 32 return antenna elements used for downlinking telemetry and tracking data.

GROUND SEGMENT

New spacecraft in the TDRS constellation will be backwards-compatible with existing Space Network user services even as they launch with contemporary technology. This includes the essential flight system, but it also includes upgrades to a powerful ground segment that make the whole architecture work.

The two primary ground facilities sit near Las Cruces, New Mexico at the White Sands Complex and the facilities are being upgraded to accommodate the new K, L, and M spacecraft. Another facility sits in Guam, giving TDRS global coverage of a user spacecraft's orbit.

Space Network users send their data through White Sands and/or Guam where the data is uplinked to a TDRS spacecraft and relayed to its destination user spacecraft, whether that is the International Space Station, a scientific satellite, or another user. Return data gets relayed similarly but in reverse. Originating from a customer spacecraft, data gets transmitted through a TDRS down to the White Sands Complex or Guam and then routed on to final destinations.

TDRS K, L, and M will facilitate years of revitalized, reliable communications, and as such the White Sands Complex is getting a functional upgrade to serve the new spacecraft. This is high-precision work, requiring demanding levels of performance. In addition, the upgrade work at White Sands cannot curtail the ongoing operation of the Space Network. From installation of new command and telemetry systems, to two Ka-band end-to-end test antenna systems, and Space-Ground Link Terminal upgrades, this interleaved in-process update will augment and connect to the system even as its everyday life continues uninterrupted.

TESTING 1...2...3...

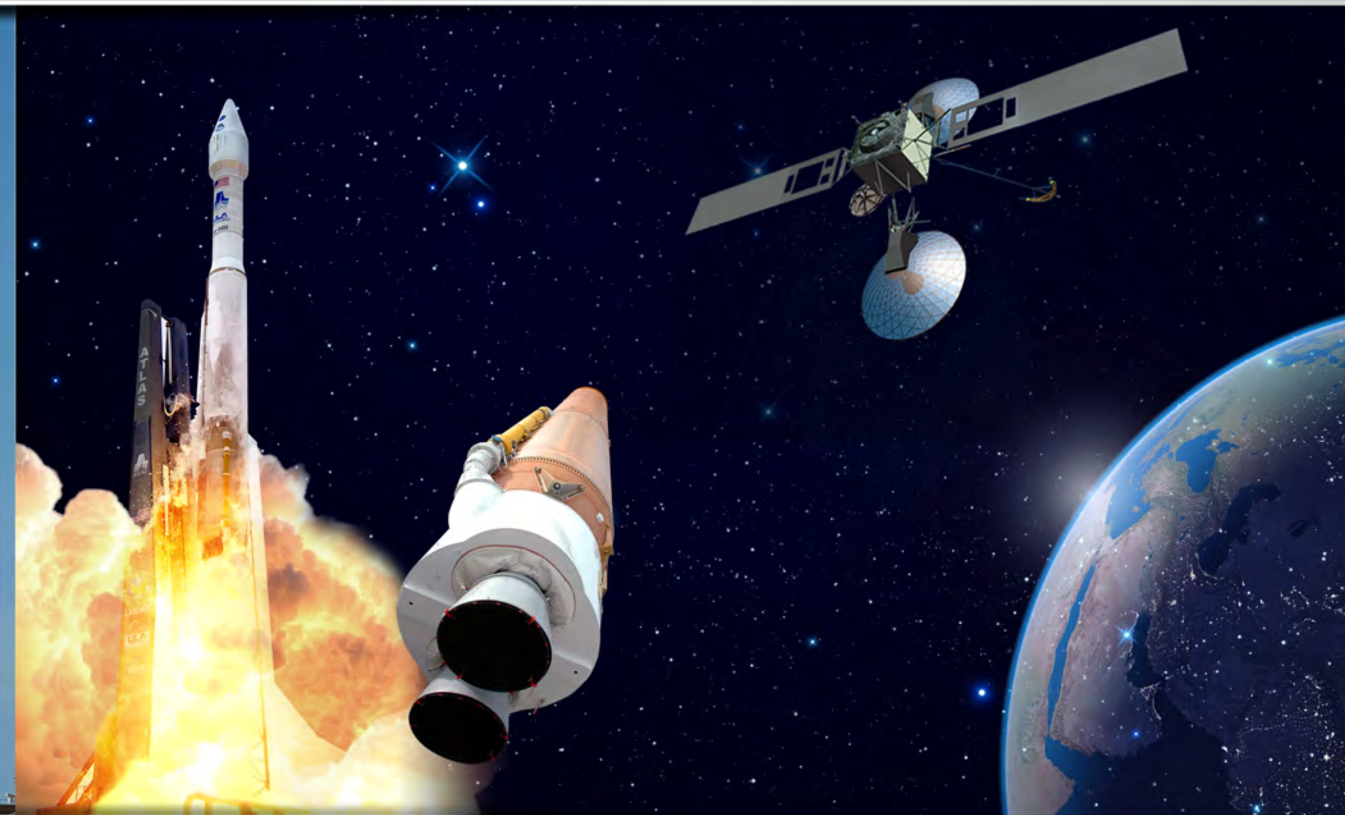
One of the most significant aspects of the TDRS K, L, and M missions is the additional flexibility they will provide to the Space Network. Operational health assessments of the Space Network are a regular, essential part of its management. TDRS spacecraft, though durable, have finite life spans, and the more they are used, the more they will need to be maintained or replaced.

TDRS K, L, and M must perform as required before they are put into active service. NASA's Space Network systems demand that there is essentially no lapse in secure, reliable data transmission. Long before their launch date, TDRS K, L, and M will be rigorously tested on the ground. Tests and checks are performed every step of the way through unit build, subsystem and spacecraft integration, and at the launch site. This enables NASA to put the utmost confidence in the operational and performance capability prior to launch of their spacecraft. Once in orbit, they will be validated and proven as performers, prior to spacecraft acceptance by NASA. No TDRS gets tasked with essential customer data before it has been accepted as a spacecraft asset worthy of Space Network operations.

DELIVERING THE NEWEST ASSETS

Beginning in 2012, the TDRS K, L, and M spacecraft are expected to blast off on Atlas V rockets, built by Lockheed Martin, heading to designated geosynchronous orbital slots 22,300 miles above the Earth.

After testing and acceptance, the TDRS K, L, and M spacecraft will go into service. They will be scheduled as the next major assets to come online when aging first generation TDRS begin to reach their performance limits. TDRS K, L, and M will be brought out of on-orbit storage and moved to new orbital positions—essentially taken out of a space-based warehouse and readied to "go live" on short notice.



That is why they are going to space before they are needed. As older assets rotate out of operation, newer ones can come online, ready to keep data flowing quickly and efficiently. This is just one more reason why the Space Network is NASA's premiere space-based network.

DELIVERING SOLUTIONS EVERYWHERE

The TDRS System provides communications services for international partnerships, research science and telemetry, rescue missions, human spaceflight, and more.

Space is already full of data and more is being produced every day. NASA bustles with activity and promises great exploration and discovery in the years ahead. From vital missions studying the Earth's changing climate, to bold journeys looking deep into space with powerful telescopes, to daily research taking place on humanity's orbiting outpost on the International Space Station, the TDRS System plays a vital role in keeping it all connected.

A wide variety of American interests rely on space-based communications, and as a dedicated expert in operations above the atmosphere, NASA regards the TDRS K, L, and M missions as essential not only to the agency, but to the continued understanding of our planet and the universe beyond.